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THERMAL ENVIRONMENTS OF STRUCTURAL FIRE FIGHTING

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Fire Environments

A great deal of research has been done to evaluate structural fires as they relate to building design, materials and contents. Only small elements of these data have been used to evaluate the thermal environment around firefighters during normal attack situations. Results from studies clearly demonstrate the severity of thermal environments at fire attack staging areas [2]*. The flow of hot gases from a doorway or through a window may be well above 500 °C (932 °F) and may extend tens of meters down a corridor or across an adjoining room ceiling. Thermal radiation from a room's open doorway or window may reach levels which will cause burn injuries to exposed skin and cause charring or ignition of protective clothing fabrics which result in burn injuries to protected skin. Surface temperatures of solids within this staging zone may easily exceed 200 °C (392 °F), and touching these surfaces without adequate protection could result in a sudden burn injury.

Fire growth characteristics have changed significantly over the last 50 years in North America. These changes may be attributed to: 1) increases in compartment fire loads, 2) increases in rates of heat release for these fire loads, and 3) differences in building construction.

Pre-flashover fires, although relatively small, develop thermal environments around them which can cause serious burn injuries to fully equipped fire fighters. Flame temperatures measured within low intensity fires are in excess of 700 °C (1292 °F). In addition, it has been reported that the total heat flux measured at the edge of a burning common wastebasket is generally in excess of 10 kW/m^2 (0.24 $cal/cm^2 \cdot s$), and in some cases it is more than 40 kW/m^2 (0.96 $cal/cm^2 \cdot s$). Air temperatures at the ceiling of test rooms with wastebasket fires ranged from 100 °C to 400 °C (212 °F to 752 °F) [2].

Many of the serious firefighter burn injuries reported each year involve fires where flashover is in progress or has already occurred, and in some cases the fires have been growing over a long period of time. Data obtained from post-flashover fire tests at NIST show that the total incident heat flux measured at the floor of a burning room can be as high as 170 kW/m^2 (4 $cal/cm^2 \cdot s$) with gas temperatures in the room averaging as high as 1000 °C (1832 °F) [2]. In this post-flashover fire environment, floor temperatures at the room's open doorway may be greater than 600 °C (1112 °F). In these types of fires, thermal radiation, hot gases and hot surfaces are typically found at relatively

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* Numbers within the brackets refer to the references cited in section 9.

great distances from the fire's source. Protection from these dangerous environments relies on firefighter training, tactics, and their protective clothing.

Protective Clothing

Firefighter's protective clothing has been designed to perform several functions. Of these, protection from heat and flame is very important. Today's firefighter protective clothing designs are based on years of field experience and research studies which addressed structural fires. Much of this work has concentrated on the fire environment where a firefighter suddenly becomes enveloped in flames. This exposure generally results in serious life threatening injuries and sometimes death. In addition, it is important to understand the conditions where many burn injuries occur outside of the flaming envelope. These intense thermal environments are generally found in locations where firefighters begin their attack on a fire.

To better comprehend the causes of these burn injuries it is important to understand: 1) the thermal environment around a firefighter when an injury occurs; 2) the performance of a firefighter's thermal protective clothing when exposed to varying fire fighting environments; 3) the activities or tactics of firefighters that contribute to a burn injury; 4) the firefighter's training that may have contributed to the injury; and 5) the fireground management issues that may have contributed to the injury. Generally, accidental injuries do not result from just one cause. An injury usually results from the accumulation of conditions or events. Improvements that will lead to a reduction in the number and severity of firefighter burn injuries are based on the understanding of all of the issues listed above and their interrelated facets that contribute to the injury.

NIST's Efforts

Over the years, NIST has worked on a number of projects to assist the fire service with special needs. Much of this work has been conducted in cooperation with the U.S. Fire Administration and through standards work with the National Fire Protection Association (NFPA) and the American Society for Testing and Materials (ASTM). As a part of this effort, this workshop is planned to provide a focal point for the identification of research needs for the fire service and the fire service protective clothing and equipment manufacturing industry.

Recent projects include the following:

NIST has participated in the development of the current NFPA standard for station/work uniforms and the standard under development for structural firefighters protective clothing.

NIST has an ongoing project to evaluate the thermal performance of trim on firefighter's protective clothing.

A NIST project is underway to develop new measurement techniques for accessing fire fighting environments and the performance of protective clothing. This will extend the current data base and assist in the preparation of the next generation of consensus standards.

A NIST project funded by the U.S. Fire Administration was conducted to development a standard for the measurement and sizing of fire and rescue services station/work uniforms. This standard has been developed through the American Society for Testing and Materials, Committee F-23 on Protective Clothing. The standard was approved and will be published in 1996.